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THE RELATIONS OF MIND AND MATTER.

BY CHARLES MORRIS.

(Continued from p. 691, July number.)

III. Development of the Nervous Function.

IN the last section the mechanism of the nervous system was considered. The modes and causes of its special development, and particularly the influences controlling the evolution of the cerebrum, now call for consideration. As already said, consciousness may, for all we know to the contrary, attend every nervous manifestation. But consciousness in that clearly defined and centralized condition which we call the psychical is the outcome of a long era of development through which the nervous mechanism has attained a high degree of specialization. At first excessively vague and faint it gradually grows stronger and more definite, until it reaches its ultimate in the vigorous, clearly defined and highly developed consciousness of man.

This result has been in great part an outgrowth of the growing sensitiveness of animal life to external energy. In the lowest forms this sensitiveness is undoubtedly very slight. In the Protozoa it is probable that touch is the only sense that has any degree of strength, though it seems evident that these animals are somewhat affected by influences emanating from substances at minute distances. Whether the vague sensations which attract the Protozoa to their food arise from physical emanations of the nature of smell, or from some heat or light influence, cannot well be determined. In many of the lower Metazoa there is no indication of any superior sensory powers. In sessile forms, indeed, the powers may be yet lower. The sponge, for instance, may possess only the sense of touch, resident mainly in its cilia. The fixed polyps may possess no higher sensitiveness, though in the free forms, such as the Medusæ, there is an evident display of more varied and delicate sensitiveness.

Yet in all the lower forms of animal life one thing is evident. External energy does not force its way into the body in any very great quantity, and it is quite possible that every sensation may call forth a motor response. This, indeed, seems to be the case in yet higher forms of life. The sensations are so limited in number that there can readily be a motor response to every sensation, and there is no reason why there should be a change from the primitive system of direct and immediate communication between the organs of sensation and the organs of motion. If in these forms intermediate ganglia exist, their sole duty may be that of a division of the current of energy and the drafting it off to the proper muscles.

As we ascend to higher forms of animal life, however, a more developed sensitiveness appears. This is a necessary result of animal development. Higher life conditions require superior powers of perceiving prey or enemies, and greater quickness in pursuit or flight. For this, sensitiveness to more and more distant impressions, to more delicate conditions of energy, and to a greater variety of emanations becomes requisite. The originally general sensitiveness must become specialized, and the nerves attain varied endings suitable to the reception of diversified modes of vibration or contact.

This absolutely necessary consequence of the development of animal form yields another consequence of considerable importance. If the sensory organism becomes highly developed and capable of receiving delicate impressions both from near and far, the inflow of energy must become so great and continuous that a motor response to every sensation will become impossible. There must be some means of checking the inflowing current and preventing the whole of it from reaching the muscles, or the body will wear itself out from the very superiority of its organization. If the sensory currents be permitted to reach the muscle fibers these cannot but respond, and would thus be steadily in the condition of fatigue and incapability. It necessarily follows that a full development of nervous susceptibility is impossible unless in some method the excessively numerous external energies which beat upon the body can be prevented from bringing all their force to bear upon the muscles.

This is the secondary phase in the development of the nervous function, and nature has chosen two methods of attaining the requisite end. In the one case, as the nervous substance grows more susceptible its sensitive terminations are covered by an indurated material, through which energy cannot readily force its way. The special organs needed to receive the more delicate forms of energy are developed only on limited tracts of the body, and touch and temperature alone are capable of affecting the whole surface. With the great mass of animals the effects of temperature are checked by some sort of protective covering, while largely in the Invertebrata, and to some extent in the Vertebrata, the effects of touch are diminished by a thick armor of scales, horn or shelly matter. In the sessile and inactive forms only a small portion of the body is usually exposed to sensory influences, the remainder being incased in solid armor through which no ordinary impression can penetrate.

As animals grow superior in organization, however, the need of swift and varied motion renders this hard covering a disadvantage, and it is thrown aside, exposing the whole body to the assaults of energy, while the organs of special sense grow constantly more and more delicate and varied in their susceptibility. In these cases, then, the body is invaded by an enormous multitude of sensory currents, which, could they all reach the muscles, would cause a serious loss of physical energy. To check this inflow the second method referred to comes into play. The nerve currents are forced to traverse ganglia and pass through the fine fibrillæ of the cells, which, like fine wires in the electric circuit, check the current, only permitting a portion of it to pass, while the remainder outflows into the ganglion as heat, or is converted into some more special mode of energy.

But this alone would not answer the purpose. In all high animal organisms it is necessary that the inflowing energy should be under special control. Some power of discrimination must exist, or must arise through the action of natural selection, to decide which currents of sensation shall pass onward to the muscles, and which shall be partly or completely checked. Only in this way could the nerve currents be prevented from calling up general and indefinite muscular responses, instead of the particular and well adapted responses necessary to yield the motions demanded by the best good of the economy. This is the third element in nerve evolution, and needs now to be considered.

It is well known that the nerve fiber is a very imperfect conducting material as compared with the metal of the electric circuit. How it conducts is an unsettled question. Its current resembles that of electricity in being simply a motor influence, perhaps in both cases set free by chemical change at the starting point of the circuit. Whether it resembles electricity in being a sort of radiant vibration through solid matter cannot be told. All we know is that its onward movement is excessively slow as compared with electricity, and that the peculiar conditions of the instigating influence persist in the current. Yet though the nerve current moves slowly there is no indication that it meets any check in the conducting fiber or in the organ of sense reception. Probably every motor influence that can make its way through the outer surface to the nerve endings, of sufficient vigor to induce chemical action in or otherwise affect these endings, produces a nerve current without reference to its character. And every such current received by the nerves is transmitted and apparently even strengthened as it flows inward.

How is it, then, that some such currents pass directly onward to the muscles, while others are checked and disappear as current influences? There is strong indication that the ganglia perform this duty. The diminution of the diameter of the fiber in the nerve cell is a precise equivalent of the method adopted to produce the same effect upon the electric current. But the point here to consider is that of the evident discrimination displayed. In the sympathetic nerve system there is no evidence of such discrimination. There is a checking influence exerted, but it acts upon all currents alike. Each fiber probably passes through a chain of ganglia, each of which lowers the intensity of the current until it is finally unable to force its way further. Thus the distance to which a sympathetic current will flow depends upon its original strength. When, for instance, in the process of digestion the sympathetic nerve extremities are excited by the contact of food, certain muscles are affected, and produce the peristaltic movement of the intestine. If the contact influence is slight, this movement will be slight and local. If contact be vigorous the effect will grow more energetic and extend further, while a wider range of glands will be excited to action. If the contact influence be abnormally vigorous the effect will pass onward from the sympathetic to the spinal nerves, and the cerebrum be notified of the abnormal condition, while its motor lines of connection with the sympathetic nerves will be called into activity. We have every reason to believe that it is the ganglion not the fiber that thus diminishes the energy of the current. And the distance to which this current can travel depends on its vigor and the number of ganglia through which it is able to force its way.

The same is the case with the cerebro-spinal nerve system. Nerve impulses of a character that is usually checked may force their way inward if exceptionally vigorous, and act upon the muscles. And significantly, in such cases, the motion produced is not special and definite but vague and general. The impulse, when it has forced a passage through the ganglia, does not select one motor channel in preference to others, but makes its way over the most conductive portion of the general motor system and calls many widely separated muscles into action. In this we have an indication of the original action of the nervous system, such as existed before specialization began and such as yet seems to exist in the sympathetic system.

The action of the ganglia, then, appears to be at once repressive and discriminative. Certain motor influences seem more capable of forcing a passage through the ganglionic resistance than others. The principle here involved seems to be that every motor influence of a new or unusual character is resisted, and ready passage is only allowed to motor influences to which the fibrillæ have become adapted. And here natural selection has come actively into play. Let us suppose the animals of a certain species to be subject to a definite series of motor impressions, each of which makes it way through the gangliar obstruction and tends to flow out generally to the muscular organs. Yet being insufficient in quantity to occupy every nerve, it will follow the largest, or those over which it finds the most open channel. Thus while the responsive movement might be somewhat general, certain muscles would obtain a surplus of the current and respond more vigorously than the others. In such a case natural selection must rapidly operate. The movements of some individuals would prove protective. Others would perish. And on the principle that the current of energy finds easiest way over the channel which it has already traversed, this particular motor influence would pursue its old channel in preference and be resisted by the other nerves. In like manner others of the sensory impressions might gain other favorite channels, and every sensation in time produce a particular action, adapted to the highest good of the animal.

But if the nerve fibers are only readily conductive to familiar motor influences, and if the gangliar cells resist all unusual sensory currents, another element comes into the situation. It is not only a question of the selection by the sensory currents of certain motor nerves in preference to others, but also of making their way at all through the ganglia. A new sensory current may in some animals pass onward and produce motion. In others it may fail to reach the muscles. Natural selection would act here also, and might preserve the individuals which failed to respond to this sensation. Thus in a single animal some sensations will come to produce a certain motor response, other sensations another response, and still other sensations no response, and only the individual which is affected in just this manner can survive, since any other series of movements or non-movements would cease to be protective. Such an animal would be a correctly adapted reflex organism. No conscious or psychic powers would be necessary for its preservation.

The repression of the sensory current by the ganglia is probably a developmental characteristic of animal life. It only became necessary when sensation became active and abundant motor energy penetrated the body. It was absolutely necessary for the good of the economy that every sensation should not produce a motion, and the original nerve cells developed into ganglia, partly through this need of repression. These checked the great mass of the motor impulses, only permitting familiar ones to follow their ordinary channels. Yet such repression was not an intelligent one. It was largely governed, in fact, by the comparative vigor of the current. The principle seems to be that every sensory current, if sufficiently vigorous, may make its way through the gangliar resistance and affect the muscles. But currents of a special kind, which have already established a familiar channel, need less vigor to make their way through the ganglia, though even these are checked if very feeble. Finally special currents which have been repeated a great number of times may make their way onward even if very feeble. And in every case an abnormally strong current, even if it be of a kind that has established a familiar channel, will force itself to some extent upon other nerves and produce general and indefinite motions. This is the material out of which natural selection chooses its new adaptations. Finally a nervous organism thus specially adapted to surrounding conditions may be hereditarily transmitted, and a special series of reflex actions or resistances become inherent in the species.

The next question to be considered is, that of the disposition of this repressed current energy. So far, in accordance with the electric analogy, we have considered it as transformed into heat. Such is what must become of it in a purely reflex organism, whose whole duty is to let certain currents pass and to repress others. But only in general cases does the repressed electric current become heat. In particular cases it becomes magnetism, mass motion and other forms of energy. Such seems to be also the case with the sensory current. As the checked electric current may be so employed as to produce a permanent condition or modification in certain matter, so is the checked sensory current. Memory results. That is to say that some substance contiguous to, or forming part of, the ganglion becomes permanently modified by the checked current of energy and assumes a condition which is persistent. And the change thus produced is not identical in character for every condition of energy, but varies with every variation in the producing cause. Thus the special character of the sensation is indicated in the particular effect it has exerted on the modified substance.

Such seems to be the character of memory. It is a condition produced by a motor influence. But motion can act only upon substance. And wherever it yields a localized, permanent, inherent effect this effect can only be an organizing one, exerted upon some substance. No motor effect can persist unchanged in any substance except it take part in the organization of that substance and produce in it some permanent modification. And it is quite within the limits of possibility that such a new condition may react on the current-bearing fibers and reproduce motor energy in the latter. Such seems to be the characteristic of memory. It is not necessarily conscious. Memory, as a rule, persists outside the range of consciousness. But it is necessarily a definite and permanent condition in something, and the word *something* necessarily signifies *some substance.*

Thus the current of motor energy which forces its way from external nature into the body, and is borne inward over the channel of the nerves, yields two opposite effects. When it reaches the muscles its effect is disorganizing. It causes chemical disintegration with an outflow of general energy, in which that of the nerves is merged and lost. When it is checked in the ganglion it seems to exert an organizing effect, perhaps attended by chemical integration, or the formation of chemical molecules of a high order. As to this, of course, nothing can be said, but that it yields a specialized effect for every special mode of sensation, and that this effect is permanent, the phenomena of memory prove. And no such effect can be produced by motion upon substance except it take part in the organization of that substance. Motion otherwise related to substance must flow out and disappear. Only the motion to which formation is due persists in any molecule or organized mass.

Possibly every ganglion has its memory. But it is much more probable that in the continued development of the nervous system, as superior or more centralized ganglia originated, the function of the lower ganglia became simply distributive, and they ceased to exert a repressive influence upon the current. Thus in a vertebrated animal, for instance, it is not improbable that the discriminative power of a spinal ganglion lies between its sending a sensory current directly to some muscle or sending it upward towards the cerebrum. It is a question of short circuiting the current, or of transmitting it to the central office. To the extent that reflex action has been established in the Vertebrata this short circuiting is the method pursued. It is the normal method in the sympathetic nerves, whose current makes its way to more and more central ganglia only as it grows in strength or becomes unusual in character. It is the method in many of the cerebro-spinal nerves for actions that have become habitual, like those of walking, for instance. Only when the regularity of step is in some way interfered with does the sensory current force its way to the cerebrum and arouse consciousness.

In nerve development, then, an early stage is the appearance of the ganglion with its discriminative and repressive powers and its memory record. A later stage is the appearance of several ganglia, one more central to the whole nervous system than the others. In this case, as we may conceive, the function of the inferior ganglia becomes confined to discrimination between sending a sensory current directly to the muscles or onward to the central ganglion. The power of final decision and repression of the current may be confined to the latter, and it may become the sole seat of memory. This centralization makes continuous progress through the lower life forms. It is clearly indicated in the insects, yet here it is doubtful if it has gained ascendency over reflex action, to which the great mass of insect motions seem due.

For this reason the loss of the head section in certain insects seems very slightly to decrease their motor powers.

As we ascend through the Vertebrata, however, nervous centralization rapidly proceeds. The cephalic ganglion, or mass of cephalic ganglia, grows more and more predominant over the inferior ganglia, and the sensory currents are diverted more and more fully towards this central region. Throughout the whole upward range the phenomena of nerve development indicates that reflex action grows less and less, and conscious action more and more declared. In certain fossil vertebrates of huge form, the mass of the inferior surpasses that of the cephalic ganglia, indicating a great degree of reflex action. Throughout the fossil series cephalization seems to steadily increase, indicating a growing superiority of conscious over reflex action.

Yet this change was only made by slow stages, and an interesting intermediate stage seems to have intervened between reflex and habitually intelligent action. This is the stage of instinct, in which reflex action and consciousness seem to be combined. In this stage the sensory currents, on reaching the inferior ganglia, seem to partly follow an habitual channel to the muscles, partly to pursue a channel to the central ganglion, where they awaken consciousness. It is a usual stage in the change from fully conscious to reflex action. In every such case intelligence may exercise some controlling function, with a possible modification of the reflex action. Finally, in the highest animals, the upward channel has become the habitual one for all but the most deep-seated or incessantly continued sensory impressions, and intelligent has grown more and more dominant over reflex and instinctive action, until in man it has become the controlling agent in the great sum of actions.

There is a principle, already stated, to which this increasing cephalization seems due. The nervous system is not readily conductive to unusual sensory impressions. It has become so to ordinary impressions, each of which has established for itself a habitual channel. But every unusual impression is checked at the ganglion, and can only make its way onward if of considerable strength, and then over the general motor system, not over any particular motor nerves. If this sensation becomes an ordinary one, natural selection decides whether it shall gain some settled channel of outflow to the muscles, or shall be finally checked at the ganglion. And another result of great importance is that every such unusual impression, thus partly or wholly checked in its course, produces the effect of memory at the ganglion. Thus a record is laid up in the memory of every unusual impression, which is vivid at first but grows less and less so with every repetition of this impression. Finally, when a particular sensation grows habitual it may cease to affect the memory record. It has already made a deep impression there, and it subsequently is received with less and less consciousness of its existence. If it passes on to the muscles it may do so utterly without affecting consciousness, or become completely reflex.

As centralization proceeds it seems probable that all such unusual impressions are directly transmitted from the inferior to the central ganglia. In this direction there appears to be the freest channel of conduction for sensory currents. Usual impressions may have opened direct lines to the muscles, but unusual ones pursue a more open and general channel leading towards the central organ, in which the final duty of discrimination is exercised. And as a consequence, in the higher vertebrates the main center of reflex action seems to have become the ganglia at the base of the brain. In the insects the ganglia of each section seem to exert an active reflex function. This has largely ceased to be the case with the spinal ganglia of man, whose main reflex center is the cerebellum and the contiguous ganglia.

In all the higher Vertebrata a nervous organ has been developed which does not seem to exist in the invertebrate animal world. This is the cerebrum. It is a special gangliar organ devoted solely to the duty of memorizing, and one in which consciousness has become centralized. In the ant, the most intelligent of invertebrate animals, there is no apparent differentiation in the head ganglion. It is a single organ, centering in itself duties of reflex and instinctive action, and of memorizing. In the highest animals these duties have become separated. The inferior brain ganglia apparently possess the function solely of reflex action, if we may view as a constituent part of this function the diversion of unusual impressions upward to the cerebrum. That is to say, they have lost all power of checking the flow of nerve energy. Memorizing and psychical action seem confined to the cerebrum. And intermediately sensations of increasing frequency grow partly reflex and partly affect the cerebrum without calling out any conflicting orders from the intelligence. Such cases are those named instinctive. Their steady course is towards the fully reflex condition. The memory record of them may become so complete, through frequent repetition, that finally they fail to produce any effect, or to arouse consciousness. Cases of this kind are by no means confined to the lower animals, but may be found in some of the most difficult operations of the human sensory organism. In the oft-quoted case of the skillful pianist, for instance, as the fingers become habituated to a certain series of movements, attention may be more and more withdrawn from the action until it reaches the instinctive stage, a vague consciousness of the movement perhaps persisting but no intelligent oversight being necessary. Only when some change in the succession of sound is produced, however caused, does consciousness at once become again active. The element of the unusual has been introduced and the sensory current immediately makes its way in its full force to the cerebrum, arousing the powers of the dormant attention.

The cerebral organ of man does not seem to be a constituent part of the general nervous system. Its sole duties are connected with the evolution of the mind. If it be completely removed animal life does not necessarily cease. But its removal shows to what an extent the life action is reflex. The lower vertebrates may continue to live for a long time without the cerebrum, and perform most of the essential duties of life. Yet every trace of memory goes with its removal, and they act only as automata. In insects the life functions are still more fully performed, showing here an inferior dominance of the mental powers. Possibly but for the shock to the organic system by its removal, its function of memorizing might be in part relegated to the cerebellum, and the embryo state of a new mental development be produced.

According to the hypothesis of Professor Christiani,[1] devised from experiments with disbrained rabbits, the cerebrum forms a kind of secondary circuit, into which a large portion of the energies enter and are stored up, while the basal ganglia form a primary circuit, which transforms the energies into reflex motions. He found that with the removal of the cerebrum all energy was transferred into reflex motion, so that disbrained and decapitated animals displayed much stronger reflex action than normal ones. In normal animals much of this distributed energy ascends to the cerebrum, where it becomes converted into consciousness and ideas.

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[1] Journal of Physiological Society, June 20, 1884.

According to Luys the optic thalami are intermediary sensory organs interposed between the purely reflex phenomena of the spinal chord and the activities of psychical life. So the corpora striata are seated at the summit of the motor nerve system. Thus it becomes a question of gangliar discrimination whether a sensory impression, on reaching the optic thalamus, shall be at once transferred to the corpus striatum and thence through the motor nerves to the muscles, or shall proceed to the cerebrum and motor impulses descend to the corpus striatum through that channel. In this latter case we venture to hypothesize that all reflex action vanishes, and that all sensory impressions that ascend to the cerebrum end there. If subsequent action take place it must be in response to new initial energy emanating from the mind and wholly governed by the intelligence.

These considerations lead to the idea that the cerebral organ may be in an anatomical sense a secondary circuit. That is, that the nerve fibers of the body may not be in direct communication with the cerebrum. It may be possible that the sensory fibers that enter the basal ganglia are continuous through the nerve cells only with the outgoing motor fibers, and that the cerebral fibers which enter these ganglia form a circuit of their own through fibrillæ of the same cells. In such a case the influence of the primary on the secondary nerve circuit could be inductive only, and we would have a mechanism similar to that of an electric inductive system. This idea of course can have no warrant in experiment, but it is offered as a suggestion that the many close analogies between the nervous and the electric current may be completed by a condition like that of induction, which plays so prominent and important a part in electric phenomena. The sheathing of the nerve fibers by the medulla seems to be an insulating apparatus. Their naked condition in the ganglia must favor induction, and renders it possible both that the transfer of a sensory current to two or more outgoing nerves may be through induction between the fibrillæ, and that its transfer to a cerebral nerve may be through induction. It is not impossible, indeed, that the check to the sensory current in a ganglion may arise through inductive transfer of its energy to a series of fibrillæ which are short circuited in the ganglion and make no connection either with ingoing or outgoing nerves.

This hypothesis of an analogy between the action of the nervous current and that of electric induction is at least of some interest, and may be further pursued. We have argued that to this checked current the phenomena of memory are due. If it arise from the transfer by induction of the sensory current to a series of fibrillæ, forming a secondary short circuit through the ganglion (continuous, of course, as all inductive currents must be), then we would have here a new apparatus for the operation of organic forces, and one leading directly to the development of a separate cerebral organ. For, as above considered, in the development of the nervous system the check to the sensory current in the ganglia became a duty of growing importance, and the volume of checked energy steadily increased with the growth of nervous susceptibility. If, then, this check took place through the action of a separate inductive circuit, this apparatus must have developed with its increase of duty. At first confined to the same cells which transmitted the reflex current, the inductive fibrillæ may have grown in length and number, and in time gained cells of their own, with connecting fibers. Through these cells the checked current would produce its final effect, whether of memory conditions or otherwise. By a continuance of such a process the cells of the inductive circuit might become separated entirely from those of the primary circuit, forming first a cerebral layer upon the central reflex ganglion, and finally a completely separate ganglion connected only by nerve fibers with the system of reflex ganglia.

Such is conceivably the mode of origin of the cerebrum, and the character of its nerve relations with the nerves of the reflex system. As intelligence grew and the great mass of sensations were transmitted to the cerebral circuit, this organ would necessarily greatly develop, until from a series of secondary fibrillæ short circuited through one or a few cells, it became the great cerebral organ of man, with its highly important function of the evolution of the mind.

We may very briefly recapitulate the conclusions to which the foregoing arguments have led. The motor energy of the external world makes its way in various forms or phases into the animal body by the channel of the sense organs and the sensory nerves. Reaching a ganglion it is received by the cells, perhaps by many of them through the division of the fiber into its constituent fibrillæ. It either continues over its original fibrillæ to the motor nerves which issue from these cells, or is transferred, partly or wholly, to other fibrillæ by induction. In such a case it may be carried to other motor nerves, or enter upon a short local circuit and yield the local effect called memory; that is, a peculiar organizing effect in which is represented its peculiar character. Or this secondary circuit may convey it to a higher or more central ganglion, in which the same modes of distribution may be exercised. In highly developed animals it may pass through several such intermediate ganglia, and be finally, in part or wholly, transferred by induction to the cerebral ganglion. In this it exerts but one action, that whose effects we call memory, a permanent transformation produced in some organizable substance. This effect is the germ of all mental development.

(To be continued.)

AFFINITIES OF ANNELIDS TO VERTEBRATES.

BY E. A. ANDREWS.

As a group the annelids exhibit in a prominent degree both bilateral symmetry and segmentation. The former is well expressed in the adult, in the early larval stages and even at the period of closure of the blastopore, when the radial symmetry of the gastrula becomes replaced by bilateral symmetry.

Segmentation, so pronounced in the adult, is not found in what we may regard as the most primitive larval form, the Trochophora of such forms as Serpula, or as more perfectly expressed in some species of Polygordius.

These two fundamental characters, bilateral symmetry and segmentation, naturally lead to a comparison of this group with the other segmented Bilateralia, of which the Vertebrata especially have attracted attention in seeking for the allies of the annelids; or rather in the attempt to derive the vertebrates from invertebrate groups, the annelids have furnished important aid.

Of those who have paid especial attention to the subject and who maintain a close relationship between the annelids and vertebrates, may be mentioned Semper, Dohrn and Hatschek. Semper seems to have advanced the most evidence in support of his